

WFIRST STATUS

APS meeting, July 21, 2016

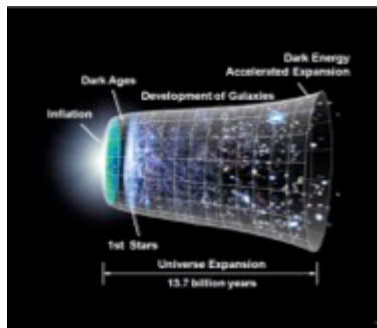
Neil Gehrels/GSFC
Project Scientist

Kevin Grady/GSFC
Project Manager

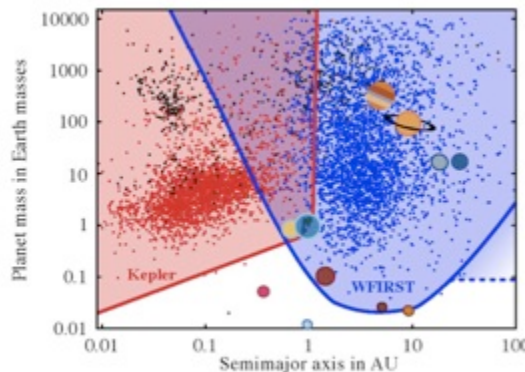
Introduction

- WFIRST highest ranked large space mission in 2010 Decadal Survey
 - Nature of Dark Energy, Exoplanet Census, NIR Sky Survey
- Use of 2.4m telescope enables
 - Hubble quality imaging over 100x more sky
 - Imaging of exoplanets with 10^{-9} contrast with a coronagraph

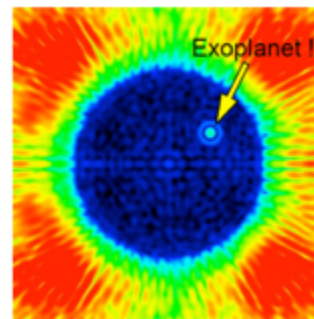
Dark Energy



Exoplanets



Microlensing



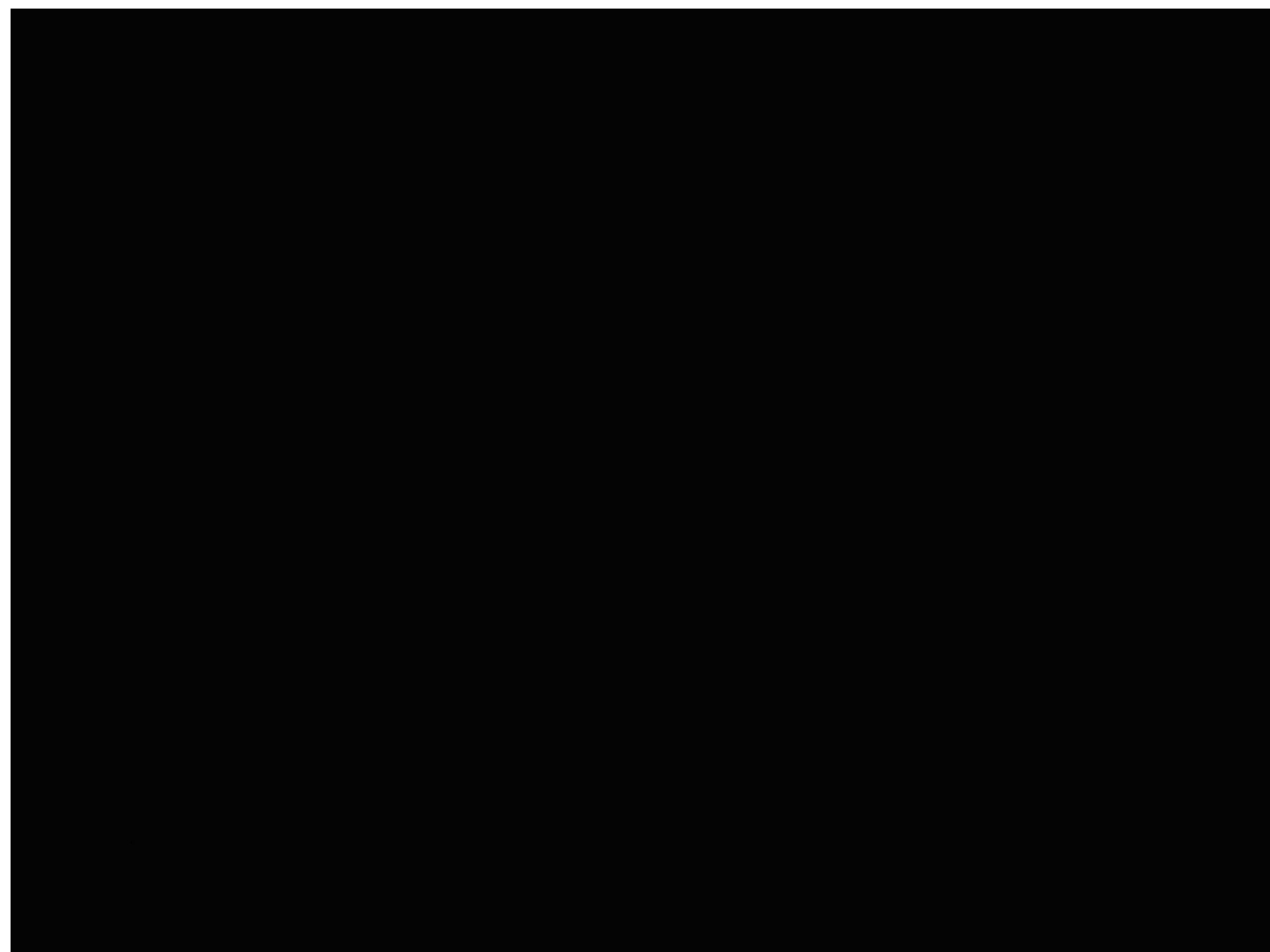
Coronagraph

Astrophysics

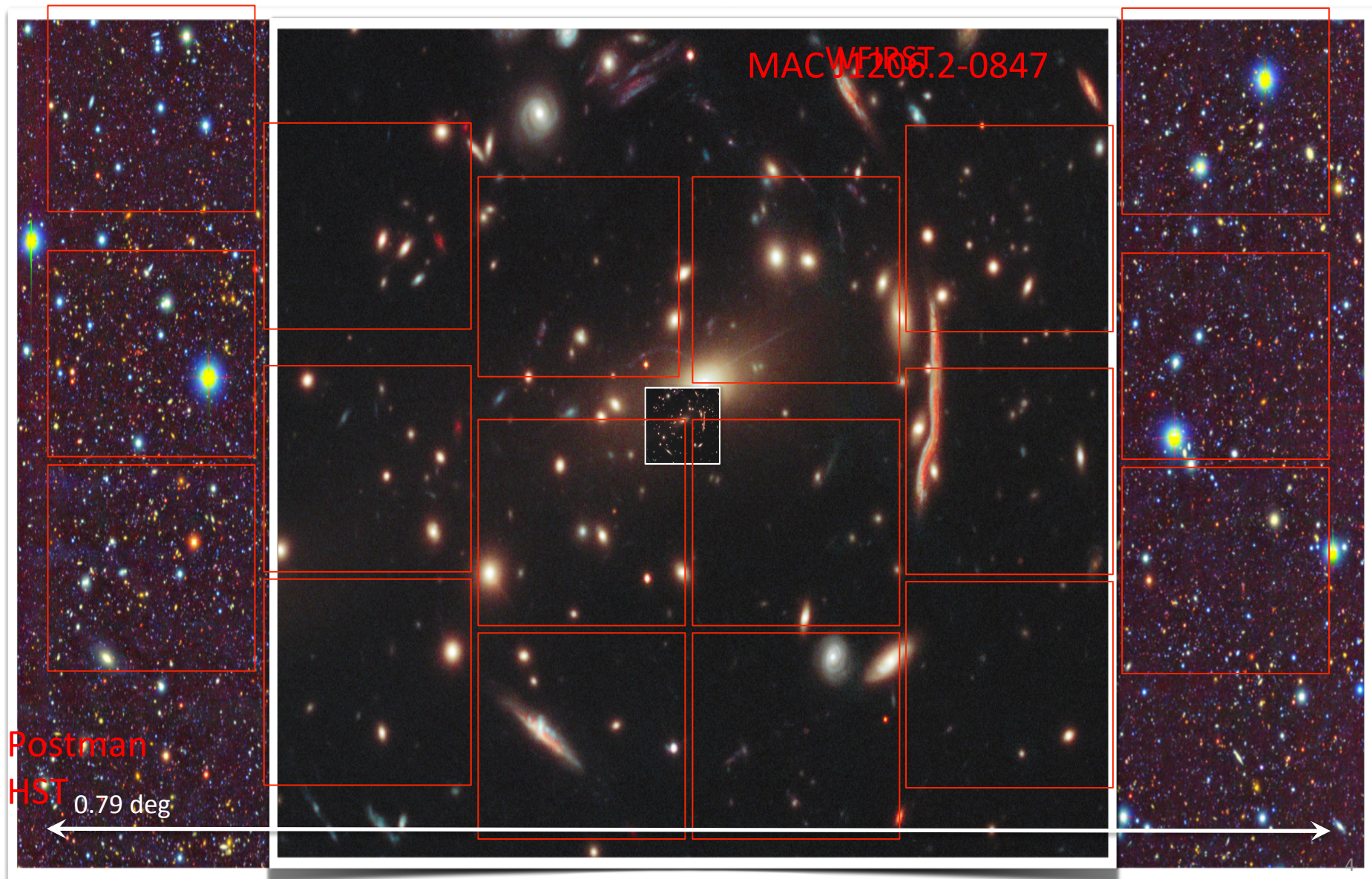


HST

WFIRST



Gravitational Lensing

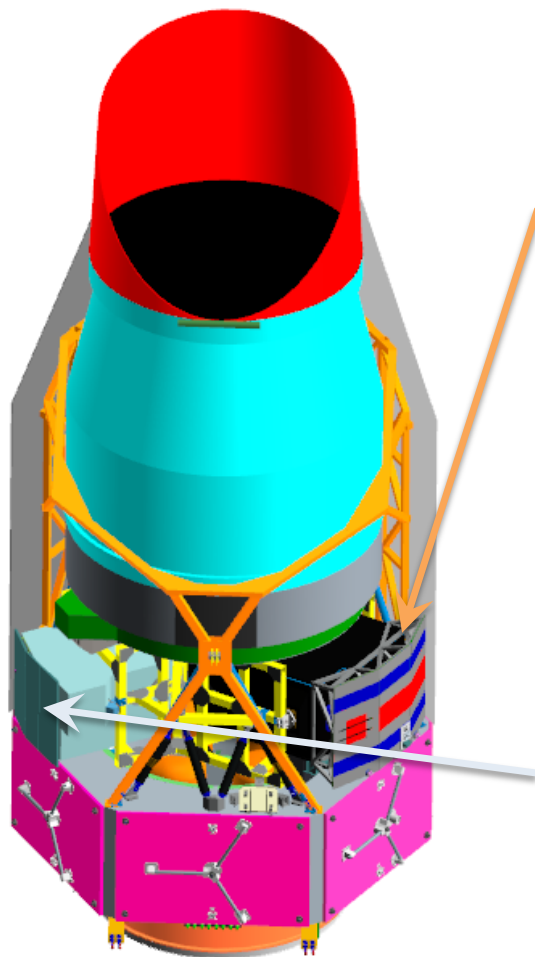


Wide Field Instrument

- *Imaging & spectroscopy over 1000s of sq. deg.*
- *Monitoring of SN and microlensing fields*
- Near infrared bandpass
- Field of view 100 x HST and JWST
- 18 H4RG detectors (288 Mpixels)

Coronagraph

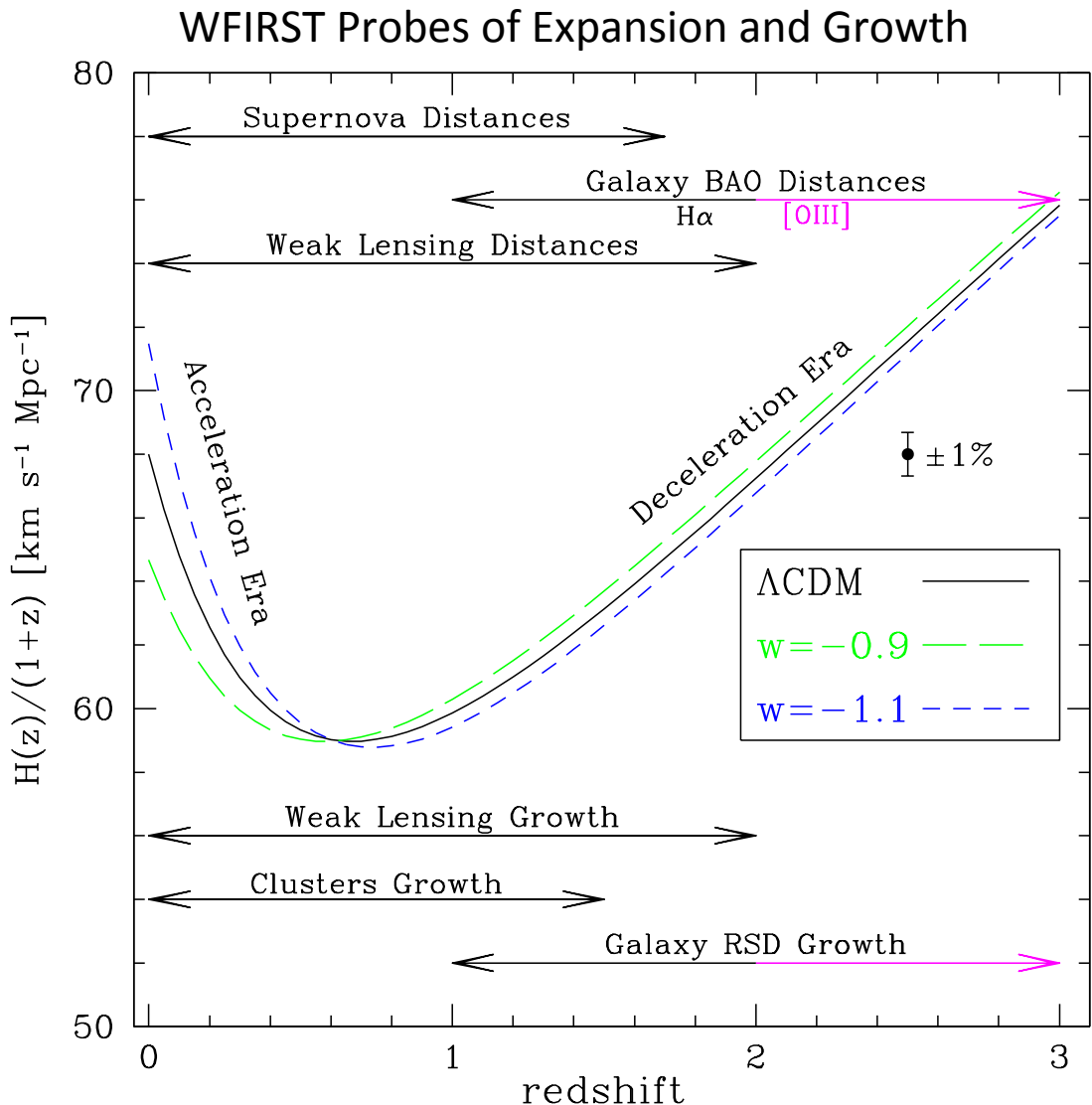
- *Image and spectra of exoplanets from super-Earths to giants*
- *Images of debris disks*
- Visible bandpass
- Contrast of 10^{11} or better
- Exoplanet images from 0.1 to 1.0 arcsec



WFIRST Dark Energy Program

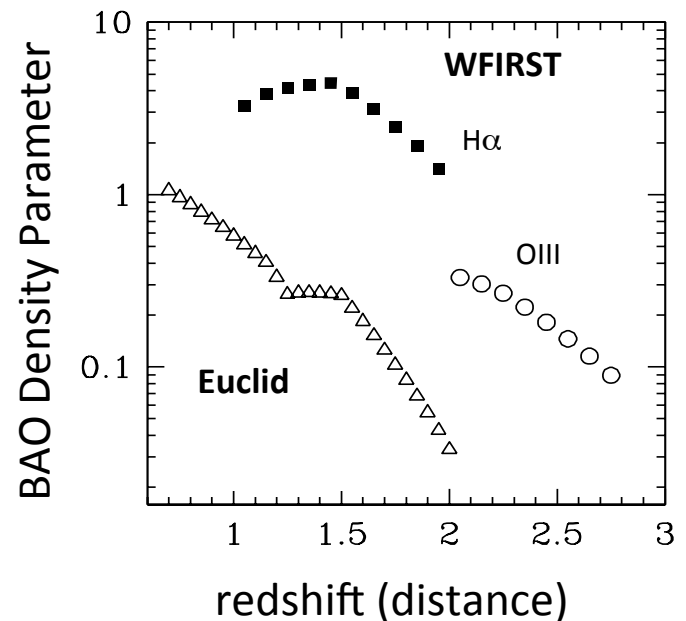
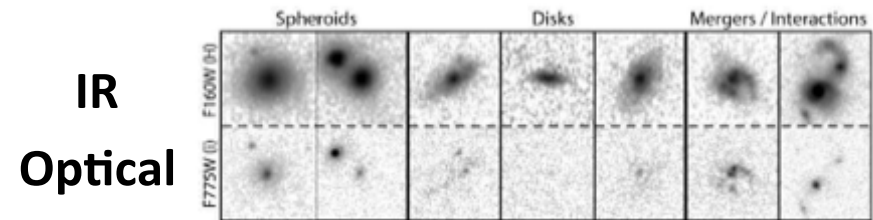
- WFIRST combines all techniques to determine the nature of Dark Energy.
- Only observatory doing such comprehensive observations
- High precision measurements will be optimally combined for the best measurement

Weinberg & SDT 2014



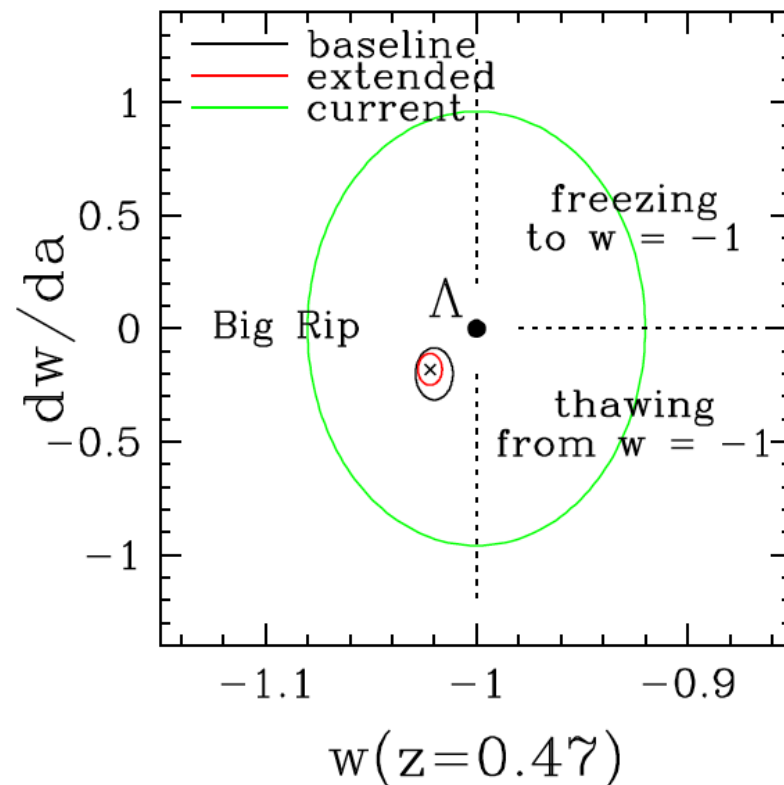


- WFIRST will be the first mission to fully exploit the powerful IR band for dark energy measurements.
- It will be much more sensitive and have higher angular resolution than any other dark energy instrument.



Potential for Discovery

- WFIRST will improve cosmology measurements 10x – 100x, with
 - greater redshift leverage
 - control of systematics
 - cross-checks of methods
- Data will be combined with
 - Euclid, LSST, DESI, ...
- Potential to:
 - reveal surprises
 - determine if new particle or new GR
 - explore relation to inflation (inflaton?)



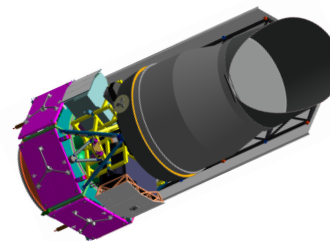
$$G_{\mu\nu} + g_{\mu\nu} \Lambda = (8\pi G/c^4) T_{\mu\nu} \quad \text{or} \quad G_{\mu\nu} = (8\pi G/c^4) (T_{\mu\nu} + T_{\mu\nu}(\text{new}))$$

Microlensing Yields

WFIRST
complements
Kepler, TESS,
Pato

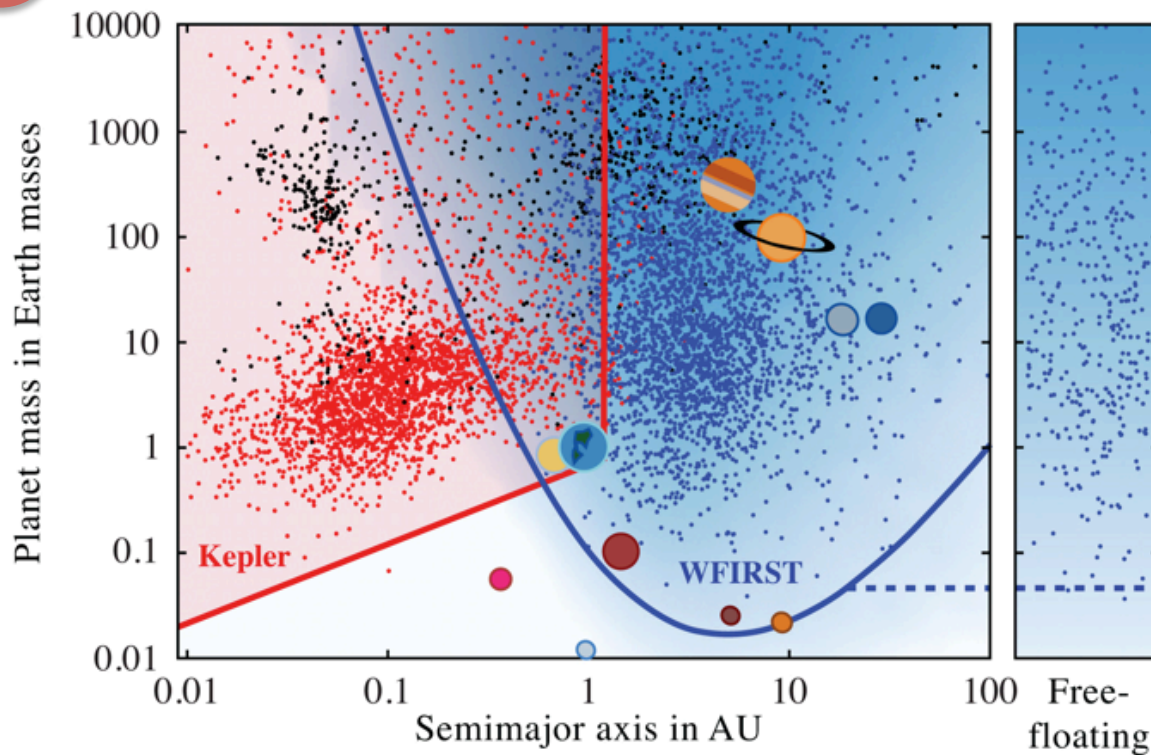


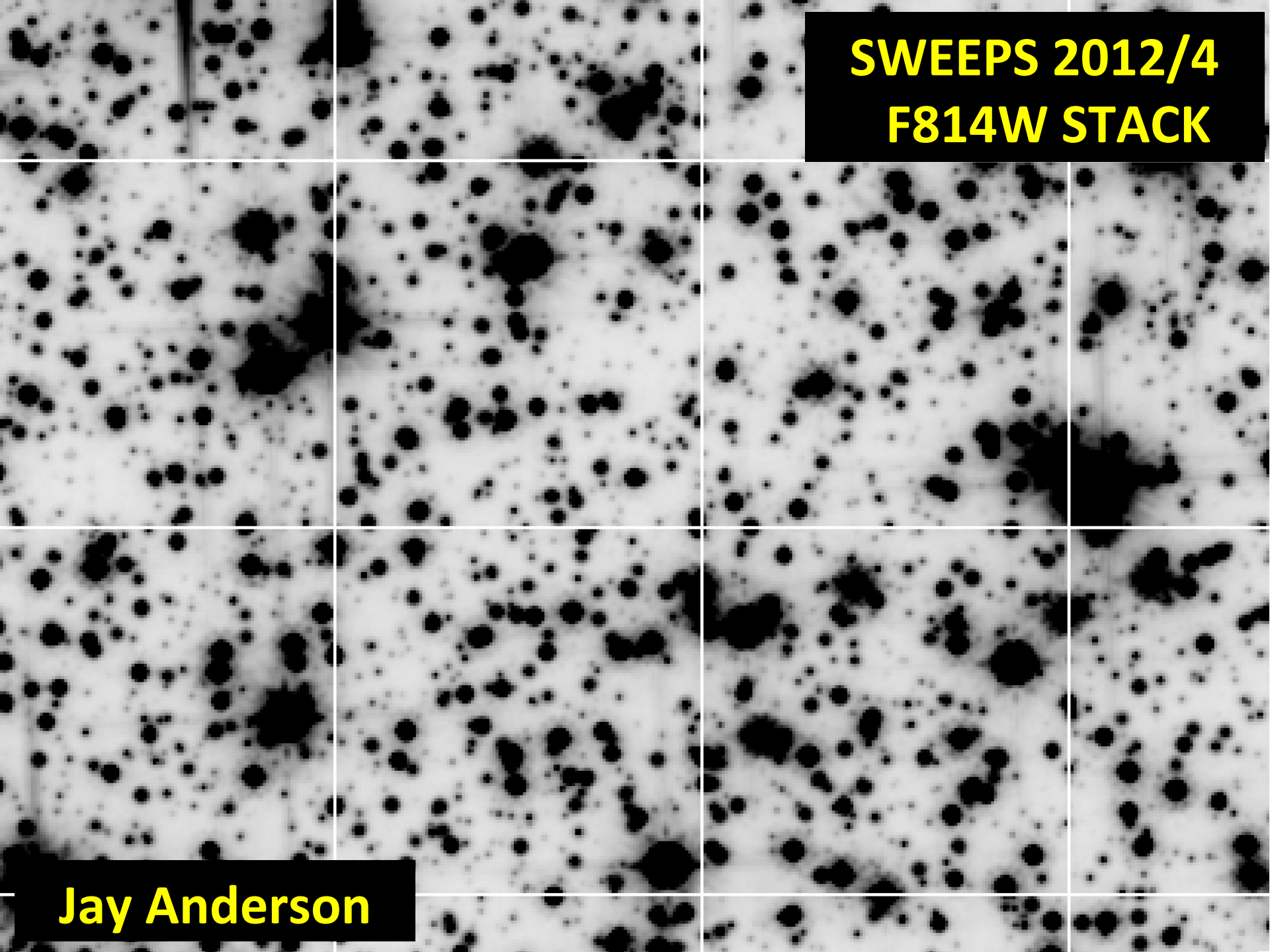
Kepler



WFIRST

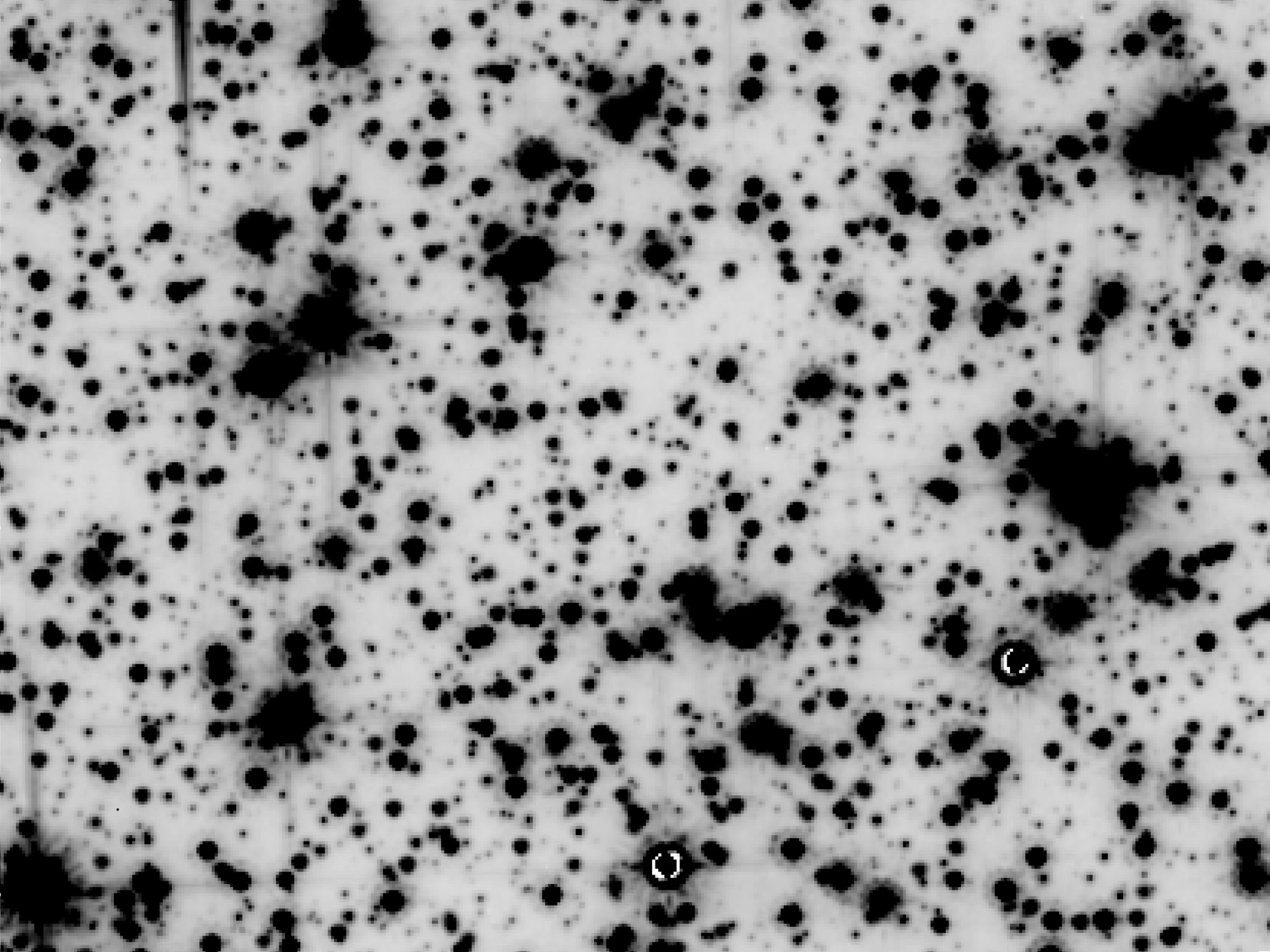
- 2600 planets
- 370 Earth mass & less
- **100's free-floaters**





**SWEEPS 2012/4
F814W STACK**

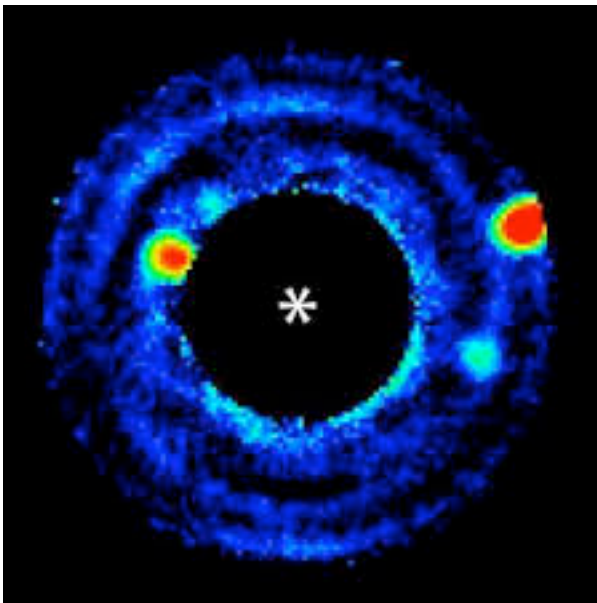
Jay Anderson



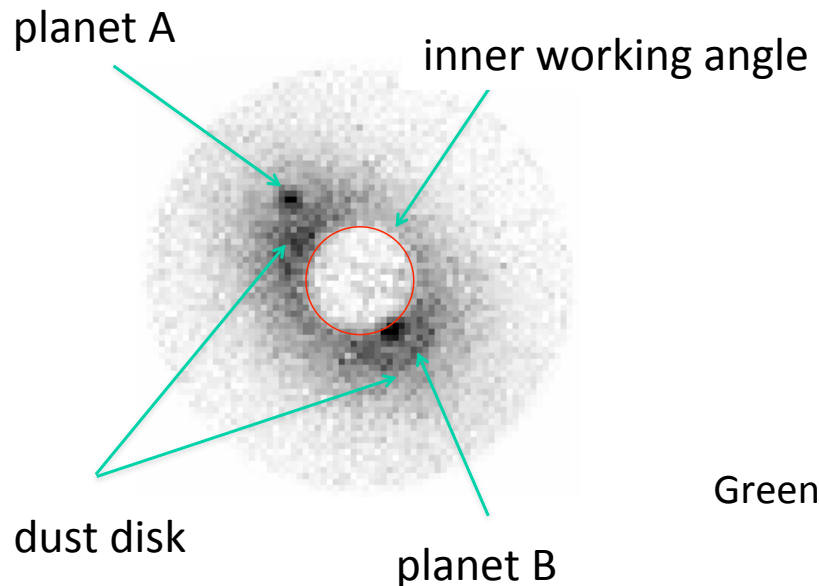
Coronagraph - Pioneering High Contrast Exoplanet Imaging

Imaging at high contrast provides direct detection and spectroscopy of exoplanets

Concept



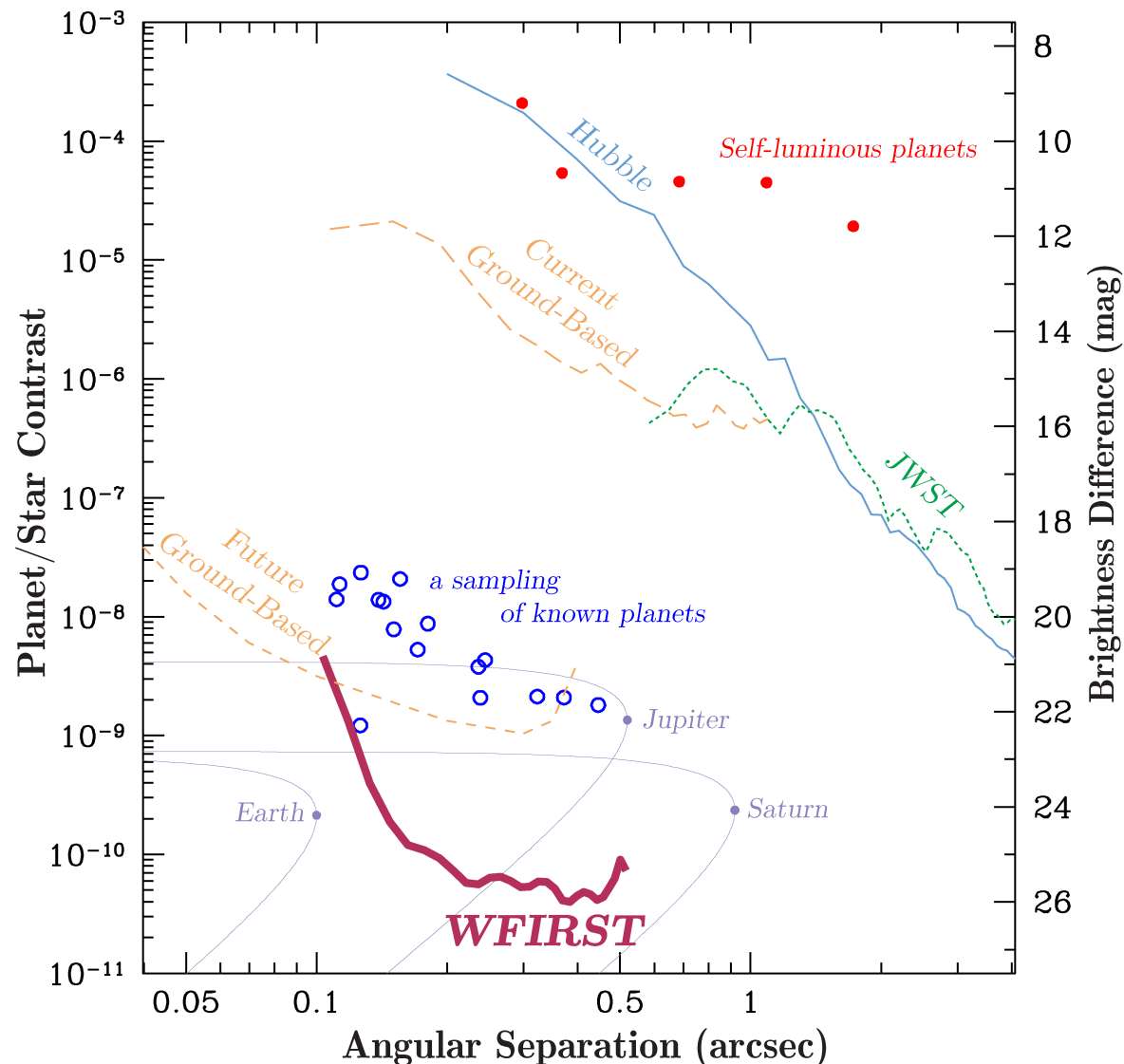
WFIRST Simulation



Greene 2015

Coronagraph Performance

- WFIRST advances key elements needed for a future coronagraph to image an exo-Earth
 - ✓ Coronagraph
 - ✓ Wavefront sensing & control
 - ✓ Detectors
 - ✓ Algorithms
- WFIRST performance predictions are exciting





Guest Observer / Guest Investigator Science

- Large area surveys will be a legacy of WFIRST
- ~100 million galaxies with $R \sim 180$ slitless spectra
~1 billion galaxies with images and photo-z's
- Large NIR sky survey will be a boon for ancillary science
 - large-scale structure
 - galaxy clusters
 - high redshift AGN (1000's of quasars at $z > 7$)
 - galaxy evolution/structure/formation at $z > 1$
 - stellar populations (brown dwarf survey)
 - star formation history
 - solar system objects
- 1.5 year GO observations
 - 25% of observing time during prime mission, 100% afterward



The WFIRST Way



The Hubble Way



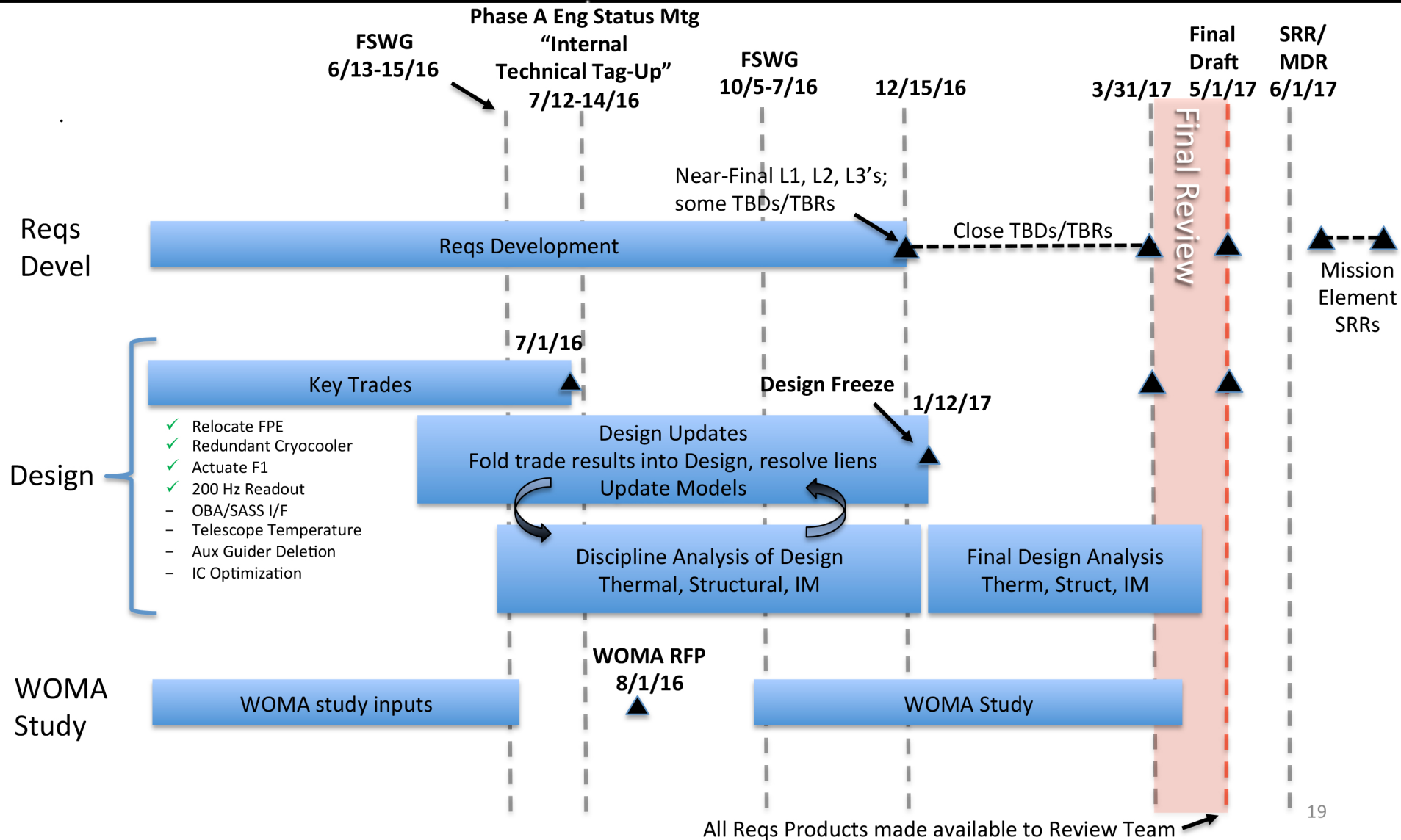
Image credit: Robert Gendler

- Continued engaging the Science Community
 - WFIRST Science Investigation Teams (SITs) funded for the next 5 years.
 - WFIRST Formulation Science Working Group (FSWG) meeting #2 held June 13-15, 2016.
 - WFIRST Preparatory Science (WPS) teams funded. 17 teams conducting science simulations and modelling.
 - Regular Wide Field and Coronagraph science team/Project working meetings.
 - High contrast imaging science workshop November 14-16, 2016 at STScI.
 - Feb 29 - March 2, 2016 “Community Astrophysics with WFIRST” large conference held in Pasadena. Next one planned for June 26-30, 2017 at STScI.

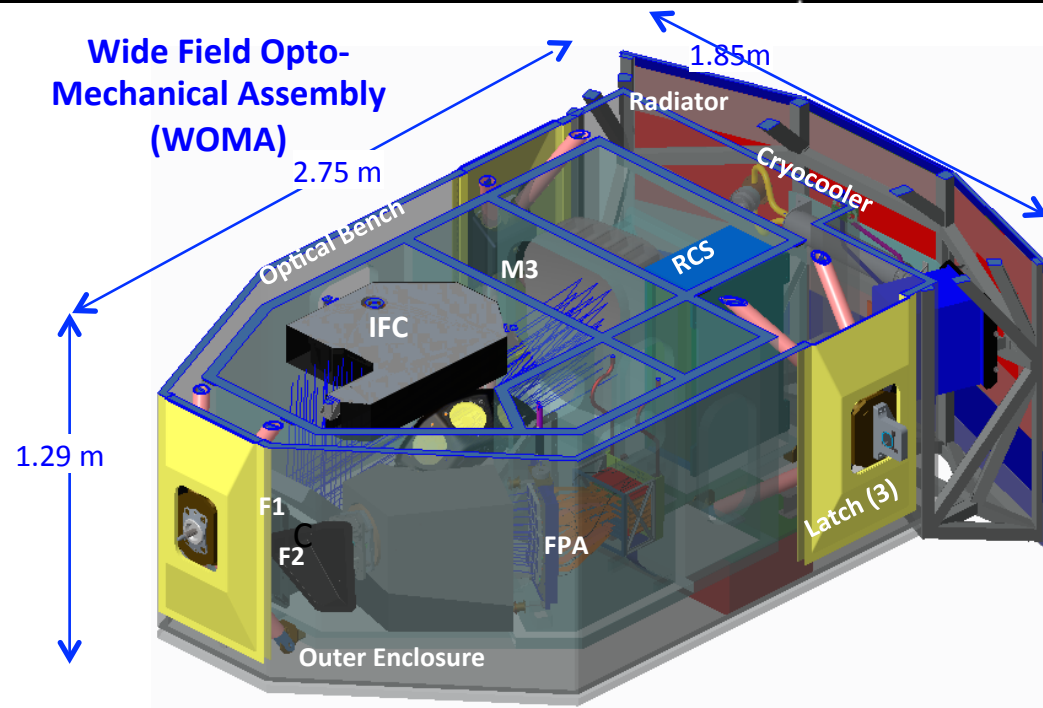
Recent Accomplishments – Proceeding Into Formulation (1/2)

- KDP-A completed in February 2016. Transitioned into Formulation Phase.
- Formulation trades in-process, many have completed. A few planned to end late CY16. Working toward design freeze early CY17.
- WFIRST technology (Coronagraph and IR detectors) continues to make great progress.
 - All milestones to date passed; significant milestones upcoming for Coronagraph high contrast demonstration and Wide Field IR detector fabrication.
- Finalizing mission implementation approach in preparation for Acquisition Strategy Meeting (ASM).
 - Establishes implementation approach for each of the WFIRST mission elements.
- Wide Field Opto-Mechanical Assembly (WOMA) industry studies (Ball, Lockheed-Martin) completed early July.
 - NASA/Industry partnership planned for Wide Field development.
 - Canada is presently studying contributing two Wide Field assemblies: Relative Calibration System (RCS) and Integral Field Channel (IFC).
 - Forward Plan:
 - Draft RFP for WOMA formulation phase study prepared.
 - Formulation phase study RFP for the WOMA planned for August 2016.
 - Study award – October 2016.
 - Development phase RFP release – May 1, 2017.

WFIRST Phase A Timeline



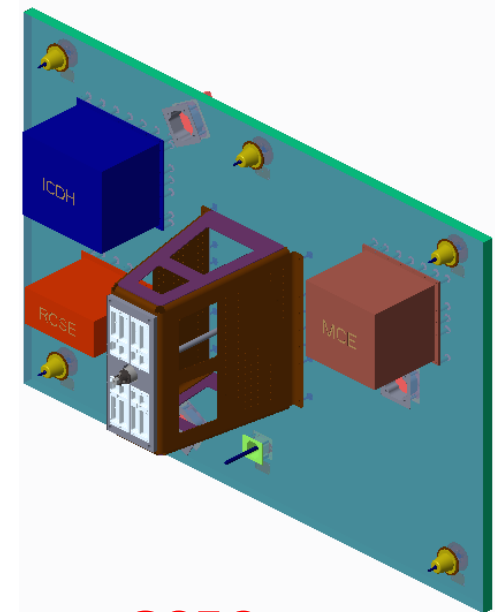
Wide Field Architecture – NASA/ Industry Partnership



Industry

- **GSFC provides: focal planes & focal plane electronics, filters & grism, and servicing interfaces.**
- **Canada potentially provides: IFC and Relative Calibration System (RCS)**
 - **GSFC provides: IFC focal plane**

Warm Electronics Module (WEM) in Spacecraft



GSFC

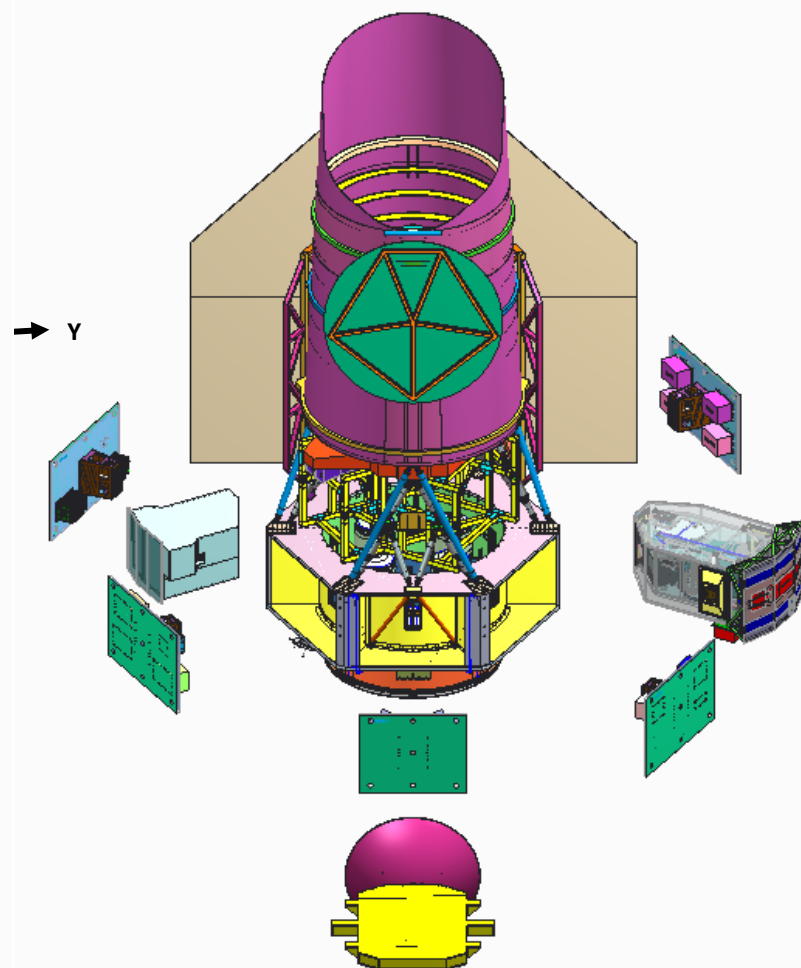
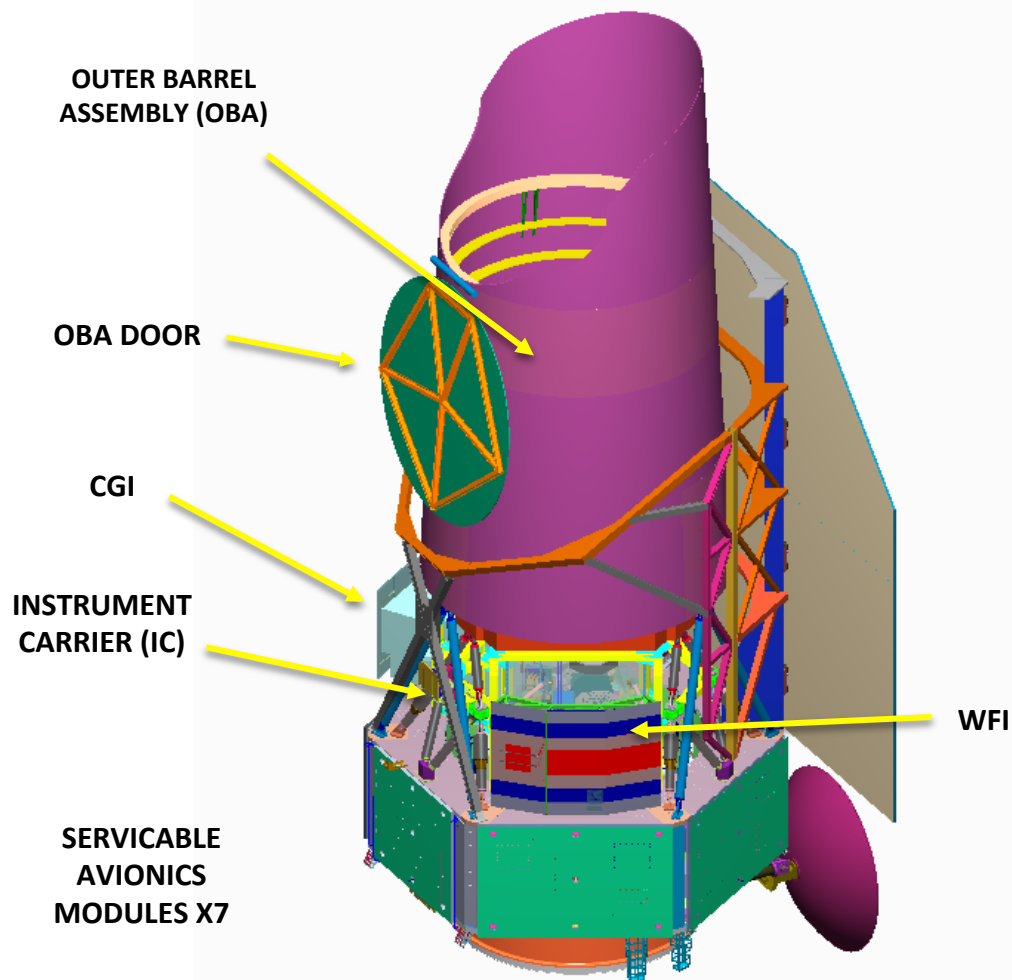
- **Industry provides: mechanism control electronics.**
- **Canada potentially provides: Relative Calibration System Electronics (RCSE)**

Recent Accomplishments – Proceeding Into Formulation (2/2)

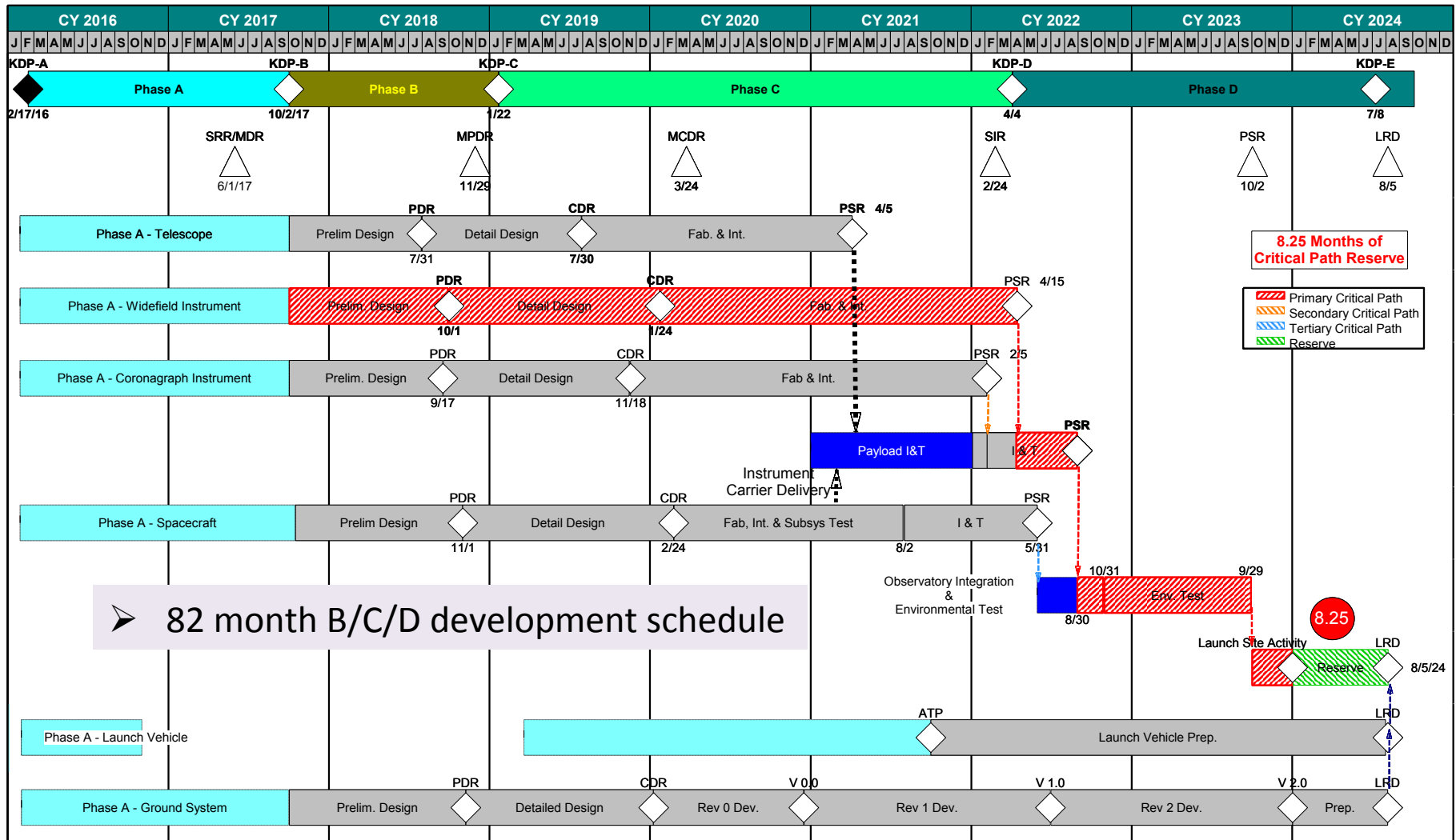
- Requirements development proceeding in preparation for Systems Requirements Review (SRR) next year.
- Budget –
 - Potential for increase in FY17 budget; \$10M from STMD committed for coronagraph.
 - FY18 – Start of preliminary design funding level will determine duration to KDP-C.
- Significant formulation effort: Bottom-up cost and schedule development.
- Project in process of developing a Descope Plan for KDP-B.
- Starshade Ready – APD directed Project to baseline “*Starshade Ready*” capability for WFIRST in Phase A, and to perform study to determine benefits/costs.
 - APD direction to implement the minimum changes necessary.
 - Opportunity to realize significant unique exoplanet investigations if starshade technology matures in next decade and such a mission is prioritized by the 2020 Decadal Survey.
 - Final decision on incorporation of the starshade ready capability to occur prior to KDP-B.
 - Early concept: small number dichroic masks & filters, mechanism added to IFS, S-band transponder & antenna for crosslink.
- International Partners – a number of potential international contributions are being considered.
 - Coronagraph - Germany/UK/Japan
 - Wide Field Instrument - Canada/France
 - Spacecraft - ESA
 - Ground System - ESA/Australia/Japan

Top Level Observatory Overview

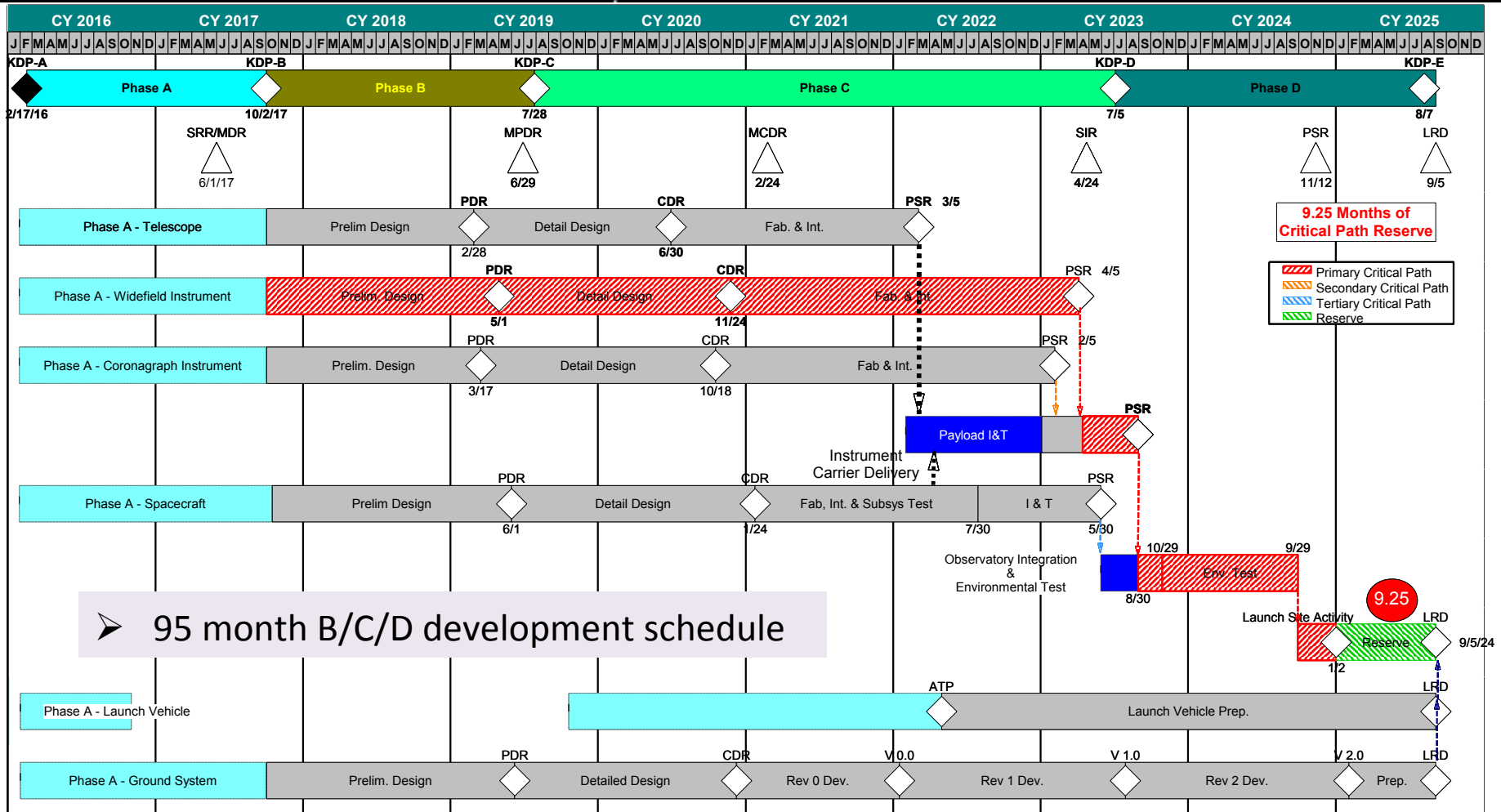
SCARF



Project Schedule (2024 LRD)



Project Schedule (2025 LRD)





Back-up



Key Programmatic Drivers

Program Level Requirements Appendix (PLRA)

- New Worlds New Horizons (NWNH) Science Objectives
 - Produce multi-band NIR sky survey: expansion history, growth of structure, planetary systems statistical census and robust Guest Observer program
- Mature exoplanet direct imaging technologies – demonstrate new internal starlight suppression techniques
 - Image and characterize giant planets and debris disks
- WFIRST is Category 1 project – Agency Program Management Council (APMC)
- Utilization of existing 2.4m aperture telescope.
- Two instruments: Wide Field and Coronagraph instruments.
- WFIRST designated Class B mission (NPR 8705.4); Coronagraph technology demonstration is designated as Class C.
- L2 orbit (current baseline) launched from Eastern Test Range (ETR).
- 6 ¼ year mission life.
- Modular spacecraft and instrument design to facilitate robotic servicing.
- Potential international partner contributions are under discussion.
- WFIRST part of Exoplanet Exploration Program (ExEP).

WFIRST KDP-A Budget Estimates

(From March APS presentation by WFIRST Project)

- WFIRST mission life-cycle cost was updated for MCR design configuration and the Key Decision Point A (KDP-A) milestone.
- The current WFIRST budget guidelines are constrained in FY18-20. As a result, the Project is working two development schedule profiles – an overguide 2024 launch date and an in-guide 2025 launch date.
- Mission cost was updated for the following:
 - increased launch vehicle costs,
 - increased science team funding (including number of teams selected),
 - design maturation (L2 changes & maturing design),
 - extended Phase A (KDP-A accelerated),
 - telescope outer barrel assembly configuration changes and
 - funding for Wide Field industry studies.
- The Project's life-cycle estimate over the range of launch vehicles and launch dates is 2.3–2.7B in FY15\$. That equates to 2.7B to 3.2B in RY\$.
- Budget includes STMD funding in FY16/17 for the coronagraph technology. STMD is considering funding portion of coronagraph flight development.
- International contributions – discussions in process for potential contributions from Europe/ESA, Canada and Japan. Contributions include elements of Wide Field instrument, Coronagraph, [spacecraft](#), and ground system.



WFIRST Summary

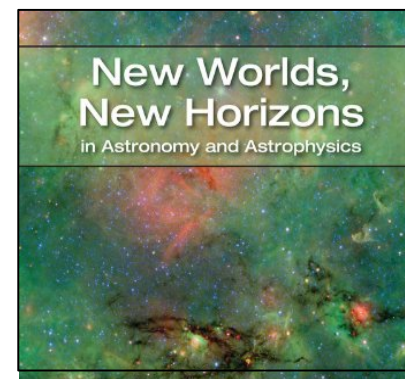


Hits 5/6 NASA Strategic Goals

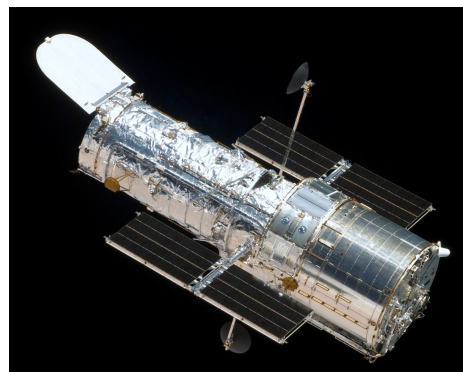
Addresses all 3 APS performance goals

#1 Priority of Astro Decadal Survey

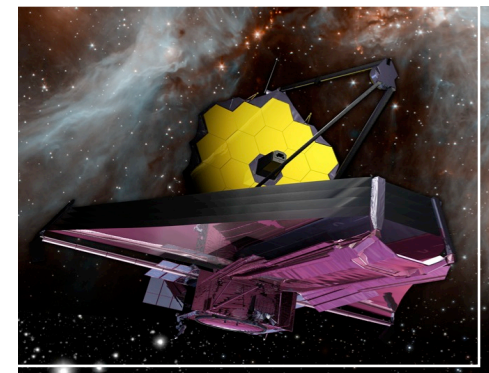
Brings the Universe to STEM education



Foundation for discovering Earth-like planets



Hubble's clarity over 10% of the sky



Complements and enhances JWST science

- **Sept 2008 – August 2010:** Joint Dark Energy Mission (JDEM) Project established at GSFC. Multiple InfraRed (IR) survey configurations studied with interim science working groups appointed by HQ.
- **June 2009:** Omega configuration developed and white paper submitted to Decadal Survey.
- **August 2010:** New Worlds New Horizons (NWNH) identifies WFIRST as #1 large astrophysics mission priority for the decade. JDEM Omega configuration identified as reference.
 - Expansion history of Universe/growth of structure
 - Perform planetary systems statistical census
 - Survey of NIR sky
 - Guest observer program
- **Nov 2010 – Aug 2012:** Science Definition Team (SDT – Schechter & Green) and WFIRST Study Office developed Interim Design Reference Mission (IDRM), a 1.3m aperture off-axis design. Final Report Aug 2012. Two Cost And Technical Evaluation (CATEs) performed.

- **Oct 2012 – Mar 2015:** A new Science Definition Team (SDT – Spergel & Gehrels) and the WFIRST Study Office developed a design reference mission utilizing the existing 2.4m telescope transferred to NASA. May 2013 and April 2014 Interim Report, March 2015 Final Report. 2 CATEs performed.
- **July 2013 – Dec 2013:** AFTA (WFIRST) Coronagraph Working Group (ACWG) recommends a coronagraph architecture for the potential coronagraph that would fly on the WFIRST mission. Science community/ ExEP/WFIRST Study Office.
- **March 2014:** NASA requested a review of the larger aperture WFIRST mission concept in late 2013 and the NRC Committee Report (Harrison Committee) concluded, “2.4m mirror will significantly enhance the scientific power of the mission.” “Responsive to all NWNH scientific goals.”

Multiple independent cost and technical assessments of IR survey Design Reference Missions have been performed by Aerospace Corp. over the past seven years, each time validating the Study Office’s estimate (10–15%), development schedule, and technical approach/risk.



Formulation Science Working Group

CHAIR & CO-CHAIRS

Neil Gehrels	GSFC
Jeremy Kasdin	Princeton
David Spergel	Princeton

SCIENCE TEAM PIs

Olivier Doré	JPL
Ryan Foley	U. Illinois
Scott Gaudi	Ohio State
Jason Kalirai	Johns Hopkins
Bruce Macintosh	Stanford
Saul Perlmutter	LBNL
James Rhoads	Arizona State
Brant Robertson	UC Santa Cruz
Alexander Szalay	Johns Hopkins
Margaret Turnbull	SETI Institute
Benjamin Williams	U. Washington

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Dave Bennett	GSFC
Chris Hirata	Ohio State
Nikole Lewis	STScI
Aki Roberge	GSFC
Yun Wang	Caltech / IPAC
David Weinberg	Ohio State

EX-OFFICIO

Dominic Benford	NASA HQ Program Scientist
Ken Carpenter	GSFC Science Center
Roc Cutri	Caltech / IPAC Science Center
Jeff Kruk	GSFC
Jason Rhodes	JPL
Wes Traub	JPL
Roeland van der Marel	STScI Science Center

- Wide Field Instrument (WFI) GSFC
 - Provides wide field imaging and spectroscopy in support of the dark energy surveys and the microlensing survey.
 - Provides integral field spectroscopy in support of the supernova survey and weak lensing photometric redshift calibrations.
 - Provides guide star data for observatory fine pointing.
- Coronagraph Instrument (CGI) - JPL
 - Provides high contrast imaging and integral field spectroscopy in support of exoplanet and debris disk science.

